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**Center for Space Power
Texas A&M University**

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NASA's CENTER FOR COMMERCIAL DEVELOPMENT OF SPACE

Johnson Controls is a 106 year old company employing 42,000 worldwide people with \$4.7 billion annual sales. Though we are new to the aerospace industry we are a world leader in automobile battery manufacturing, automotive seating, plastic bottling and facilities environment controls.

The battery division produces over 24,000,000 batteries annually under private label for the new car manufacturers and the replacement market. We are entering the aerospace market with the nickel hydrogen battery with the help of NASA's Center for Space Power at Texas A&M. Unlike traditional nickel hydrogen battery manufacturers, we are reaching beyond the space applications to the higher volume markets of aircraft starting and utility load leveling. Though space applications alone will not provide sufficient volume to support the economies of scale and opportunities for statistical process control, these additional terrestrial applications will. For example, nickel hydrogen batteries do not have the environmental problems of nickel cadmium or lead acid and may someday start your car or power your electric vehicle.

However you envision the future, keep in mind that no manufacturer moves into a large volume market without fine tuning their processes. The Center for Space Power at Texas A&M is providing indepth technical analysis of all of the materials and fabricated parts of our battery as well as thermal and mechanical design computer modeling.

Several examples of what we are doing with nickel hydrogen chemistry to lead to these production efficiencies can be seen in the following designs.

Our first space qualified design was influenced by a joint effort with Comsat and resulted in a 32 V, 24 Ah, 10" diameter battery that has sustained over 6,000 LEO cycles (16 charge-discharges/day) to 44% DOD at 10° C. This battery is unique in that all of the cells are packaged in a common pressure vessel (CPV) instead of the traditional individual pressure vessel (IPV) for each cell. This is a natural evolution of the technology and results in lower weight, size and cost with equal or higher reliability. The challenges in making what appears to be a simple packaging transistor are significant and a number of aerospace companies have tried and given up.

Through the use of Texas A&M's microcalorimeter, we have obtained excellent thermal transfer data which was then applied to the computer model.

We have moved from the initial 10" diameter battery with its fixed cell housing to a 5" diameter with individual heat fin dishes that permit excellent heat transfer and also ideal manufacturing tolerances for high speed assembly.

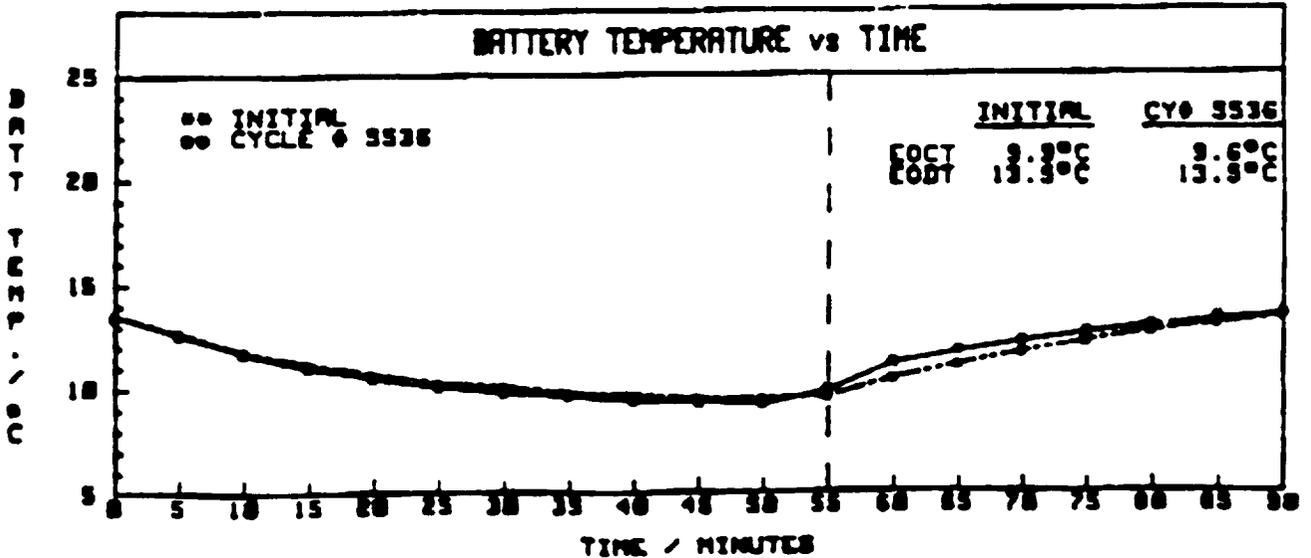
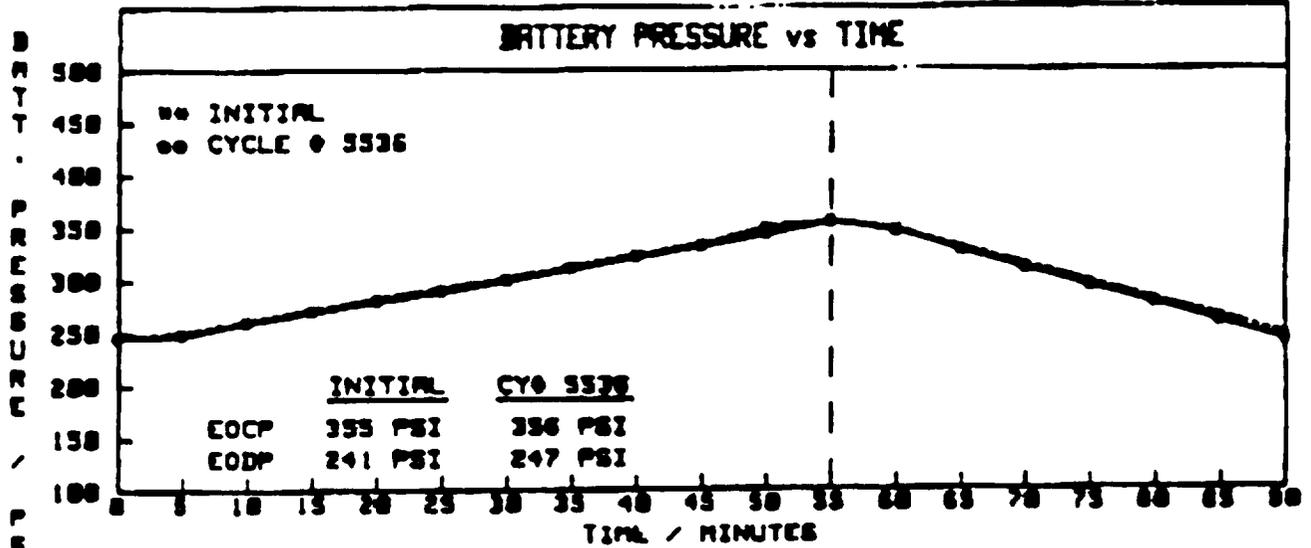
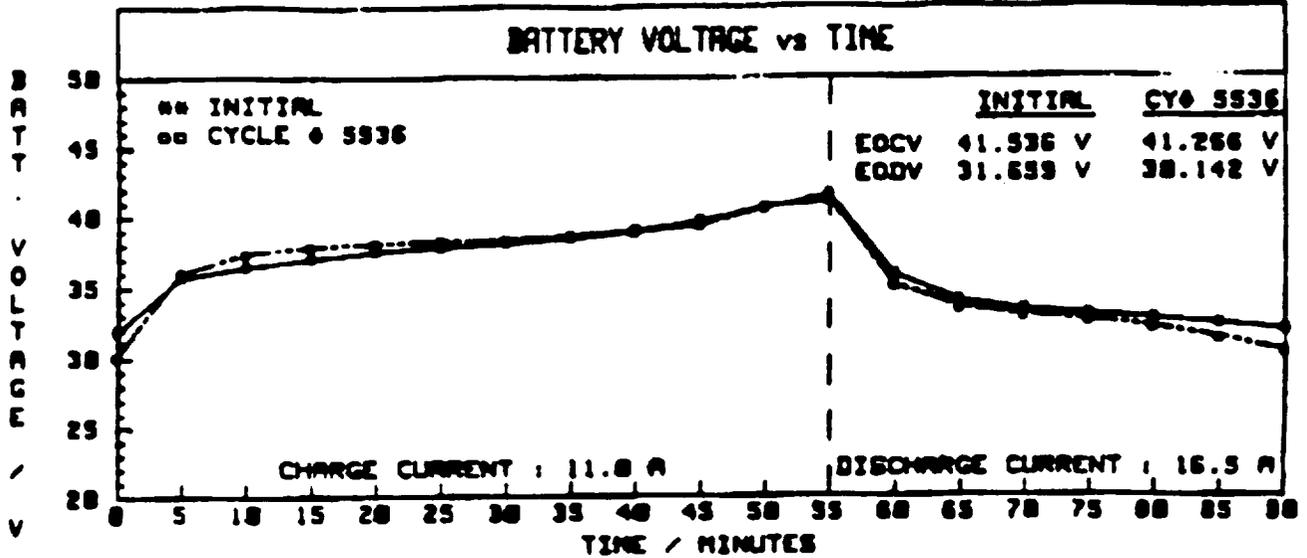
With the aid of Sandia National Laboratories we have also made two iterations of stationary batteries. One 7 kWh has operated successfully for over two years and four newer versions of 4 kWh capacity for one year.

Even with the high first cost of nickel hydrogen CPV batteries, their long cycle life over other chemistries allows the true cost to be half that of lead acid over 10 years or more.

FEATURES OF PATENTED JCI CPV DESIGN

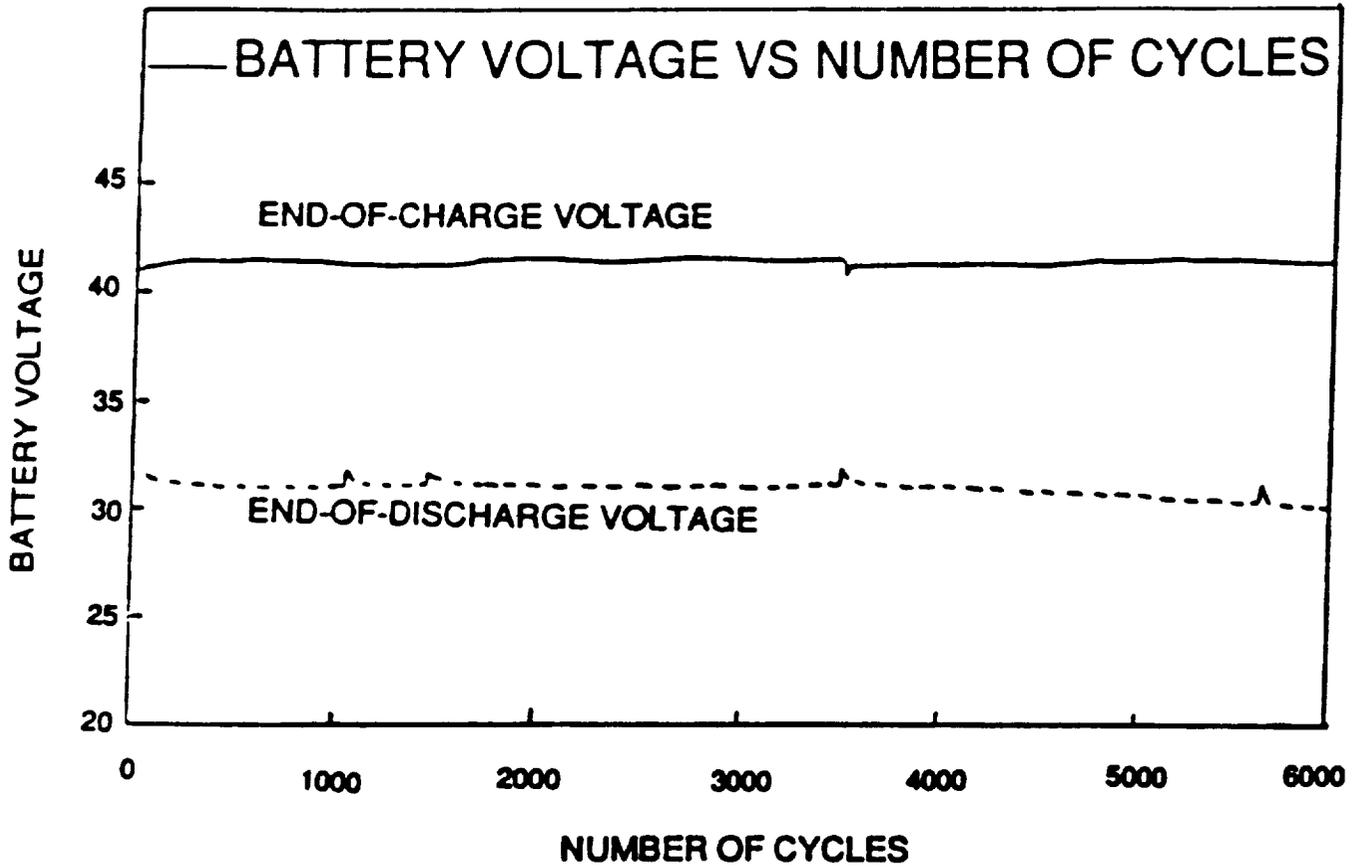
- MULTIPLE CELLS IN A SINGLE VESSEL**
- STANDARD NICKEL HYDROGEN CELL COMPONENTS**
- BACK-TO-BACK POSITIVE CONFIGURATION**
- ABSORBER BETWEEN POSITIVE ELECTRODES**
- CELL ENCLOSED IN ECS**
- VENTED ECS ALLOWS HYDROGEN ACCESS**
- VENT LOCATION ENSURES IN-CELL RECOMBINATION**
- DOUBLE ECS ENHANCES RELIABILITY**
- RADIAL HEAT FIN IMPROVES THERMAL TRANSFER**
- WELDED INCONEL 718 VESSEL**

90-MINUTE CHARGE/DISCHARGE PROFILE FOR CPV BATTERY # 1



CPV PROTOTYPE BATTERY #1

44% DOD LEO CYCLING TEST



CHARGE DISCHARGE PROFILE

TEMPERATURE = 10°C

